

REPORT DOCUMENTATION PAGE

Form Approved
OBM No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE April 1997		3. REPORT TYPE AND DATES COVERED Proceedings	
4. TITLE AND SUBTITLE Predicting Subsurface Optical Properties				5. FUNDING NUMBERS Job Order No. 73664007 Program Element No. 062435N Project No. Task No. Accession No. DN163736	
6. AUTHOR(S) Vladimir I. Haltrin, *Walton E. McBride III, and Todd E. Bowers					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory Oceanography Division Stennis Space Center, MS 39529-5004				8. PERFORMING ORGANIZATION REPORT NUMBER NRL/PP/7331--97-0004	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Research Laboratory 4555 Overlook Avenue, SW Washington, DC 20375-5320				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Proceedings of the Gulf Coast Section, Marine Technology Society, 23-24 April 1997, Stennis Space Center, MS *Planning Systems Inc., 115 Christian Lane, Slidell, LA 70458					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) In this paper we compare the 3-D optical field generated by the Predictive Visibility Model (PVM) with the results of <i>in situ</i> measurements of inherent optical properties obtained during the Hamlet's Cove I Experiment near the West Florida coast. Preliminary results are encouraging and show that the PVM can qualitatively predict the evolution of inherent optical properties in littoral waters.					
14. SUBJECT TERMS optical properties, PVM (Predictive Visibility Model), West Florida coast, littoral waters, spatial distributions, temporal distributions, PAR (photosynthetically available radiation), and Zaneveld's formula				15. NUMBER OF PAGES 5	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT SAR		

19981218 016

Predicting Subsurface Optical Properties

Vladimir I. Haltrin [†], Walton E. McBride III ^{*} and Todd E. Bowers ^{*}

[†] Naval Research Laboratory, Ocean Sciences Branch, Code 7331, Stennis Space Center, MS 39529, USA
Phone: 228-688-4528, fax: 228-688-5379, e-mail: <haltrin@nrlssc.navy.mil>

^{*} Planning Systems Inc., 115 Christian Lane, Slidell, LA 70458, USA
e-mail: <walt_mcbride@psislidell.com>

Abstract

In this paper we compare the 3-D optical field generated by the Predictive Visibility Model (PVM) with the results of *in situ* measurements of inherent optical properties obtained during the Hamlet's Cove I Experiment near the West Florida coast. Preliminary results are encouraging and show that the PVM can qualitatively predict the evolution of inherent optical properties in littoral waters.

1. Introduction

The prediction of inherent optical properties in littoral waters is critically dependent on the spatial and temporal distributions of optically significant constituents such as suspended sediment and biological populations. These distributions, in turn, depend on hydrodynamic transport in the coastal region and photosynthetically available radiation. In this paper we compare the 3-D optical field generated by the PVM, a computer model capable of predicting diurnal and episodic changes in near-coastal water optical properties, with the results of *in situ* measurements of inherent optical properties obtained during the Hamlet's Cove I Experiment in West Florida coastal waters. In the next section we give a brief description of gathering and processing of the experimental data, followed by an overview of the computer model and its predictive capabilities in section 3. Finally, we offer a few preliminary conclusions in section 4.

2. Experimental data

In situ data from the Hamlet's Cove I experiment were collected with two WETLabs Inc. 25 cm pathlength AC-9 beam transmissometers. These instruments collected beam absorption and attenuation data at nine wavelengths ranging from 412 nm to 715 nm. The first AC-9 was anchored as a moored unit at a depth of approximately 6.8 meters and distance of 50 meters from the shoreline. The second transmissometer was configured as a vertical profiling unit, and data was collected at nine stations transecting perpendicularly from the shoreline. The water depth ranged from 2 meters at the shallowest station to approximately 23 meters at the deepest.

The data from both instruments were post-processed according to an algorithm derived at the Naval Research Lab by Dr. A. Weidemann and T. Bowers [1], and approved by WETLabs, Inc. The data were first corrected for instrument drift by applying pertinent field calibrations. A correction was then applied to the near-infrared band to correct for differences in the instrument's initial calibration temperature and the water temperature at the time of the experiment. Next, the absorption measurements were corrected for scattering error with R. Zaneveld's formula [2]. This is necessary due to the instrument's inherent design which causes the data to be overstated. Pure water absorption values for each wavelength are then added to the data according to values calculated by Pope [3]. Pure water scattering values are considered negligible and were not

included. The data were then separated into individual time steps and the Kriging approximation was used to create data suitable for surface generation and visualization.

Below are two examples representative of the type of experimental data accumulated at Hamlet's Cove and post-processed. Figure 1a is a plot of the absorption coefficient as a function of depth at station 7 for all nine wavelengths, while figure 1b is a similar plot for the scattering coefficient.

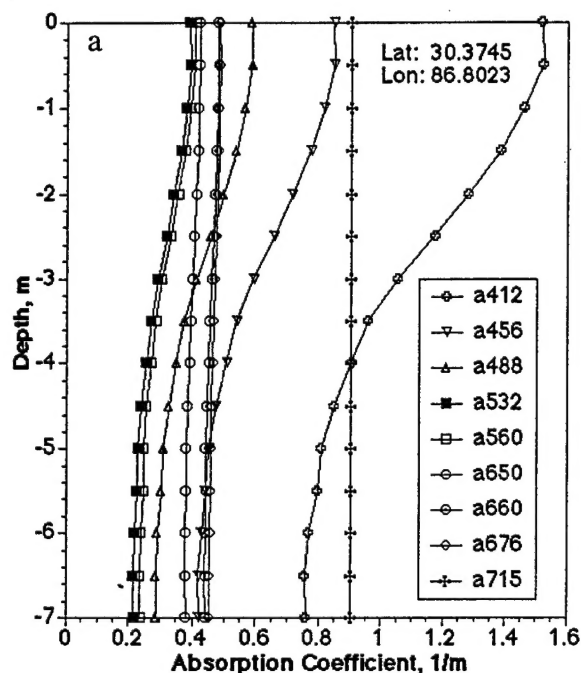


Figure 1a:
Experimental values of absorption coefficient.

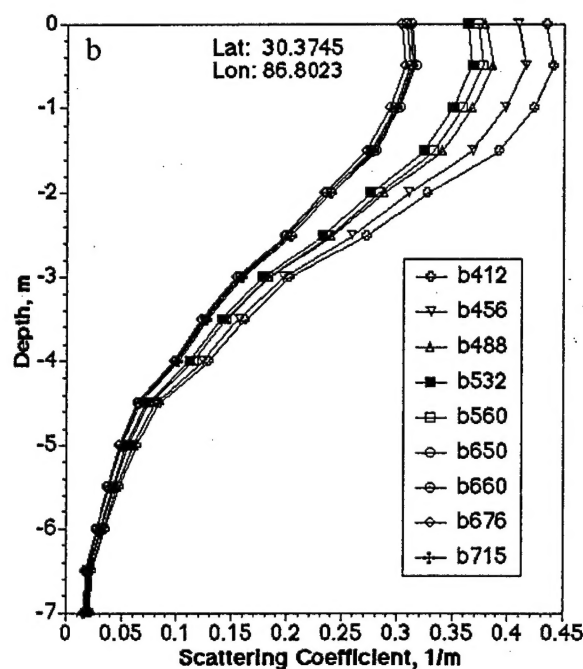


Figure 1b:
Experimental values of scattering coefficient.

Figures 1a and 1b illustrate the depth variation of measured inherent optical properties. Depth dependence is only one of the many predictive capabilities of the PVM. In the next section, the overall goal and purpose of the PVM is explained and we illustrate the temporal and spatial predictive capabilities of the PVM.

3. Predictive Visibility Model

The Predictive Visibility Model was jointly developed by Science Applications International Corp. and the Scripps Oceanographic Institution [4, 5] for the Office of Naval Research and the Naval Research Laboratory.

The PVM was designed to predict the optical properties of coastal waters from first principles using forecasts of waves, currents, river discharge, coastal geomorphology and land use. The model estimates the spatial and temporal distributions of environmental drivers required to predict subsurface scattering, absorption, and diffuse attenuation coefficients within a factor of two and also forecasts episodic changes of environmental significance. Such drivers include river discharge, tidal currents, ocean swell, bottom resuspension, plankton growth and episodic changes in storm related land runoff.

Optically important constituents in the PVM are presently limited to sediments, phytoplankton and colored dissolved organic materials. The spatial and temporal variability in the concentrations of each constituent is driven by mixing and advection in the dynamic coastal environment. Inherent optical properties of the water were calculated with the help of Mie scattering over particle size

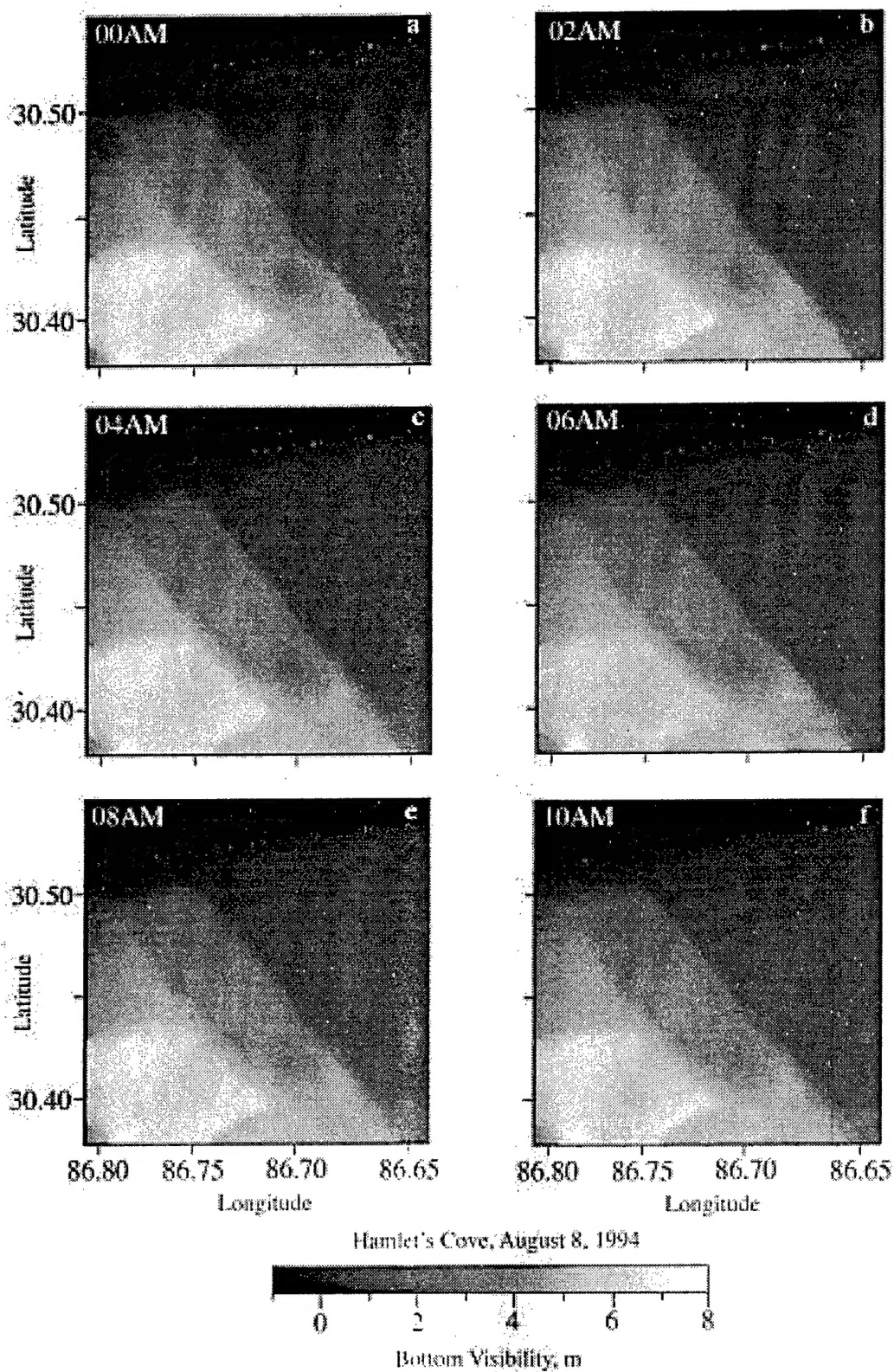


Fig. 2. Catalog of the PVM time-dependent bottom visibility for Hamlet's Cove.

distributions of each constituent. In calculations of scattering on sand and clay particles we used index of refraction data proposed in [6]. Visibility assessment was performed with the help of inherent optical properties. Estimation of the light fields was made according to [7].

A typical PVM run begins with an initialization. This step includes the generation of a 200 x 200, 3 arcsec resolution bathymetry grid, information about water elevation relative to mean sea level, offshore tidal current and direction for each 2-hour time step, and solar irradiance over the 24-hour simulation period. The other time-varying parameters such as cloud cover, air temperature, sea surface temperature, pressure and direction, sea height, swell period, direction and height, and offshore current velocity are linearly interpolated at each 2-hour time step between their nowcast and 24-hour forecast values.

For each time step, one of the outputs of the PVM is the 3D spatial variation of the inherent optical properties. In the PVM, visibility is defined as 3 divided by the total attenuation coefficient. In Figure 2 we present a catalog of the PVM bottom visibility predictions over 5 successive two-hour time steps, from midnight to 10 AM, for the Hamlet's Cove I area.

3. Conclusions

Because the Predictive Visibility Model incorporates the major environmental drivers responsible for the variability of inherent optical properties in littoral waters, it should be capable of predicting the concentrations of optically-important substances from the driving physical, chemical and biological forcing functions. Although it is not expected that the PVM predictions will be as accurate as those achievable for open ocean waters, predictions of inherent optical properties within a factor of two are foreseeable. Comparison with the collected data shows that, in spite of some discrepancies between prediction and ground truth fields, the PVM can be used for qualitative predictions and may serve as a basis for development of more robust predictive visibility models.

4. Acknowledgments

The authors wish to thank continuing support at the Naval Research Laboratory through the Littoral Optical Environment (LOE 6640-07) and Optical Oceanography (OO 73-5051-07) programs. This article represents NRL contribution NRL/PP/7331-97-0004. The authors would like to take this opportunity to thank Drs. Alan D. Weidemann and David K. Young for help.

5. References

- [1]. A. D. Weidemann, and T. Bowers, "An Algorithm for Processing AC-9 Data", Private communication (1996).
- [2]. WETLabs Inc. AC-9 Documentation and Manual, June 1994, Philomath, Oregon, 36 pp.
- [3]. Pope's Ph. D. thesis, Texas A&M University, College Station, TX, 1992.
- [4]. R. R. Hammond, S. A. Jenkins, J. S. Cleveland et al., *Coastal Water Clarity Modeling Feasibility Study*, Final Report, SAIC Technical Report No. 01-1349-03-4841-000 (CDRL A002), February 1995, 650 pp.
- [5]. S. A. Jenkins, J. Wasyl, R.R.Hammond, *Coastal Water Clarity Model: Adaptation for the Hamlet Cove Data Set*, SAIC Technical Report, July 1996, 21 pp.
- [6]. W. E. McBride III, V. I. Haltrin, C. D. Kennedy, and A. D. Weidemann, "Optical Spectral Signatures of Marine Sediments", in *Ocean Optics XIII*, 1997, (in print).
- [7]. V. I. Haltrin, and A. D. Weidemann, "A Method and Algorithm of Computing Apparent Optical Properties of Coastal Sea Waters", in *Remote Sensing for a Sustainable Future, Proceedings of 1996 International Geoscience and Remote Sensing Symposium: IGARSS'96*, Vol. 1, Lincoln, Nebraska, USA, 27-31 May 1996. pp. 305-309.